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MEMORANDUM FOR PR (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO)

13 Nov 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-AB-2000-218**  
Mead, Franklin; Larson, C. William, "Laser-Powered Vertical Flight Experiments at the HELSTF"

**37<sup>th</sup> AIAA/ASME/SAE/ASEE Joint Propulsion Conference (Statement A)**  
**(Salt Lake City, UT, 8-11 Jul 2001) (Deadline for Abstract: 08 Nov 00)**

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

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PHILIP A. KESSEL Date  
Technical Advisor  
Propulsion Science and Advanced Concepts Division

# **LASER-POWERED, VERTICAL FLIGHT EXPERIMENTS AT THE HIGH ENERGY LASER SYSTEM TEST FACILITY**

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In 1996, the Air Force Research Laboratory's Propulsion Division at Edwards AFB initiated a program that had as its main objective to launch a laser-propelled vehicle into a suborbital trajectory within a period of 5 years in order to demonstrate the concept and its attractive features. The concept is a nanosatellite in which the laser propulsion engine and satellite hardware are intimately shared. The forebody aeroshell acts as an external compression surface (i.e., the airbreathing engine inlet). The afterbody has a dual function as a primary receptive optic (parabolic mirror) for the laser beam and as an external expansion surface (plug nozzle). The primary thrust structure is the centrally located annular shroud. The shroud provides air through inlets and acts as a energy absorption chamber for plasma formation in the airbreathing mode. In the rocket mode, the air inlets are closed, and the afterbody and shroud combine to form the rocket thrust chamber and plug ("aerospike-type") nozzle. The full scale vehicle has a focal diameter of one meter and a dry mass of about 1 kg. Fully fueled, this vehicle would have an initial mass of about 2 kg (i.e., a mass fraction of 0.5), and would be launched into orbit with a megawatt-class infrared ground-based laser (GBL). It would be a single-stage-to-orbit (i.e., airbreathing with infinite  $I_{sp}$  to  $M=5$  and 30 km; a laser thermal rocket with its own on-board propellant at higher altitudes and in space) using a combined-cycle pulsed detonation engine. Once in space, the Lightcraft will use its one meter diameter optical system to provide, for example, Earth surveys with from 8 to 15 cm resolution in the visible light frequencies from low Earth orbit (LEO). Such a device is simple, reliable, safe, and environmentally clean, and could have a very high all azimuth, on demand launch rate. The current launch model under consideration would launch up to 1,000 vehicles per year, each for under \$500 of electrical power. Production costs of about \$3,000 for the spacecraft appear reasonable at present.

The Lightcraft Technology Demonstration Program was planned in three phases. Phase I, Lightcraft Concept Demonstration, was to demonstrate the feasibility of the basic concept. This phase ended in December 98. Under Phase I, performance was measured with pendulum impulse and piezoelectric thrust stands, shadowgraph studies and beam propagation energy measurements to 90 m were accomplished, a pointing and tracking system was developed and demonstrated on horizontal wire-guided flights outdoors to 122 m, and outdoor vertical free-flights approaching 30 m were successfully conducted.<sup>1,2&3</sup> Low Mach number wind tunnel tests were also accomplished with a 23-cm diameter model.<sup>4</sup> The basic conclusion of all this work was that the feasibility and basic physics of the Lightcraft concept had been adequately demonstrated, and that a much larger, 100 kW class, laser would be required to completely accomplish Phase II.<sup>5</sup>

Phase II, Lightcraft Vertical Launches to Extreme Altitudes, was initiated in January 99, and is a five-year effort designed to extend Lightcraft flights in sounding rocket trajectories to 30 km with a 100 kW CO<sub>2</sub> laser. The objective of the current Phase II vertical flight test program is to extend Lightcraft vertical free-flights to significantly higher altitudes in the range of 150 to 300 m using the 10 kW PLVTS laser.<sup>5</sup> 1/10<sup>th</sup>-scale and 1/4-scale laser-powered vehicles are being used. Currently with this size vehicle, laser flight tests are being conducted at the High Energy Laser Systems Test Facility (HELSTF), White Sands Missile Range (WSMR), New Mexico, using the currently available Pulsed Laser Vulnerability Test system (PLVTS) CO<sub>2</sub> electric discharge laser. This laser is a pulsed wave, closed cycle, 10 kW CO<sub>2</sub> laser with a pulse repetition rate of 1 to 30 pps (selectable), and a variable pulse width of 5 to 30  $\mu$ s. For flight test experiments, the laser is usually operated at about 25 pps and 18  $\mu$ s pulse widths.<sup>5</sup> The first composite, ceramic components for the laser propelled vehicle have been fabricated, laboratory tested, and flown. Performance details will be presented comparing the composite materials with aluminum which has been used up until recently. Scaling effects as a function of focal diameter will be presented, and predictions on the performance of the full scale vehicle will be made. Details of the vehicle performance during flight test experiments will also be discussed. Video footage taken during the outdoor free flight tests will be shown during the presentation.

Phase III, Lightcraft Dual Mode Vehicle, is a two-year effort designed to launch the first laser-propelled vehicle, fully functional, into space. This phase will require the construction of a megawatt class CO<sub>2</sub> laser with appropriate optics to meet the power beam propagation requirements.

#### **References**

1. Myrabo, L.N., Messitt, D.G., & Mead, F.B., Jr., "Ground and Flight Tests of a Laser Propelled Vehicle," AIAA 98-1001, 36th Aerospace Sciences Meeting & Exhibit, Reno NV, 12-15 Jan 98.
2. Mead, F.B., Jr., Myrabo, L.N., & Messitt, D.G., "Flight and Ground Tests of a Laser-Boosted Vehicle," AIAA 98-3735, 34th AIAA/ASME/SAE/ASEE Joint Propulsion Conf., Cleveland OH, 13-15 Jul 98.
3. Messitt, D.G., Myrabo, L.N., Mead, F.B., Jr., "Laser Initiated Blast Wave for Launch Vehicle Propulsion," AIAA 2000-3848, 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conf., Huntsville AL, 17-19 Jul 00.
4. Panetta, A.D., Negamatsu, H.T., Myrabo, L.N., Minucci, M.A.S., Mead, F.B., Jr., "Low Speed Wind Tunnel Testing of a Laser Propelled Vehicle," SAE International and AIAA 1999-01-5577, 1999 World Aviation Conf., San Francisco CA, 19-21 Oct 99.
5. Mead, F.B., Jr., Squires, S., Beirsto, C., & Thurston, M., "Flights of a Laser-Powered Lightcraft During Laser Beam Hand-off Experiments," AIAA 2000-3484, 36th AIAA/ASME/SAE/ASEE Joint Propulsion Conf., Huntsville AL, 16-19 Jul 00.